Behavioral Challenges in Engineering Teams

Shawn Collins

Structures & Transmissions, Rolls-Royce

Purdue Polytechnic Summit

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Contains No Technical Data

We don’t make cars

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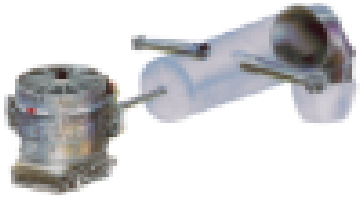
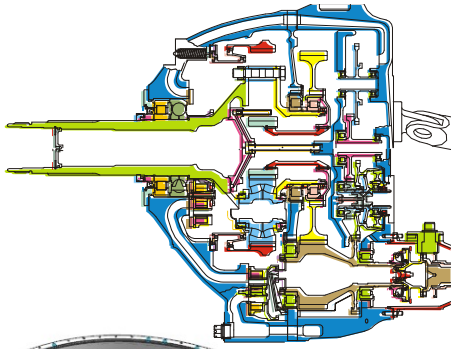
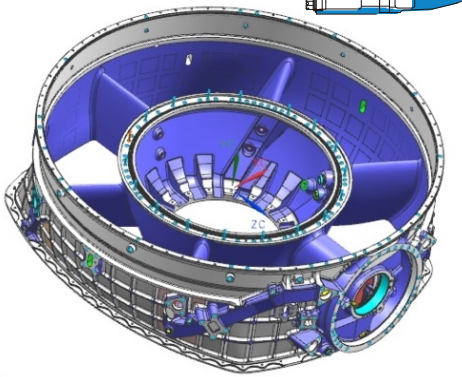
Structures & Transmissions – the technical fun

- Gears, Gearboxes

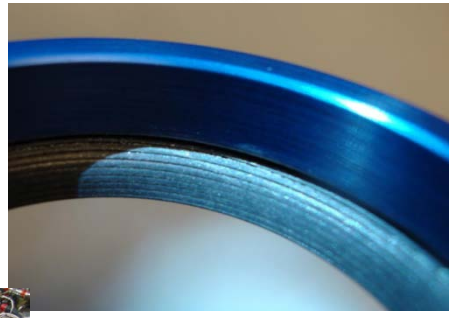




- Static Structures



- Bearings & Seals



- Clutches

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Structures & Transmissions – Distributed Teams

9000 engineers spread over 8 countries worldwide

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Agenda

Product Development Context

- Ideal: “green field” product development pipeline
- Reality: “brown field” product development pipeline

Problem Space

- Challenges that occur for engineering teams

Cross-disciplinary Solutions

- I’m an anthropologist – I see this as a social challenge

What does the research / practice overlap look like?

- Existing research themes
- Potential opportunities

Closing Points

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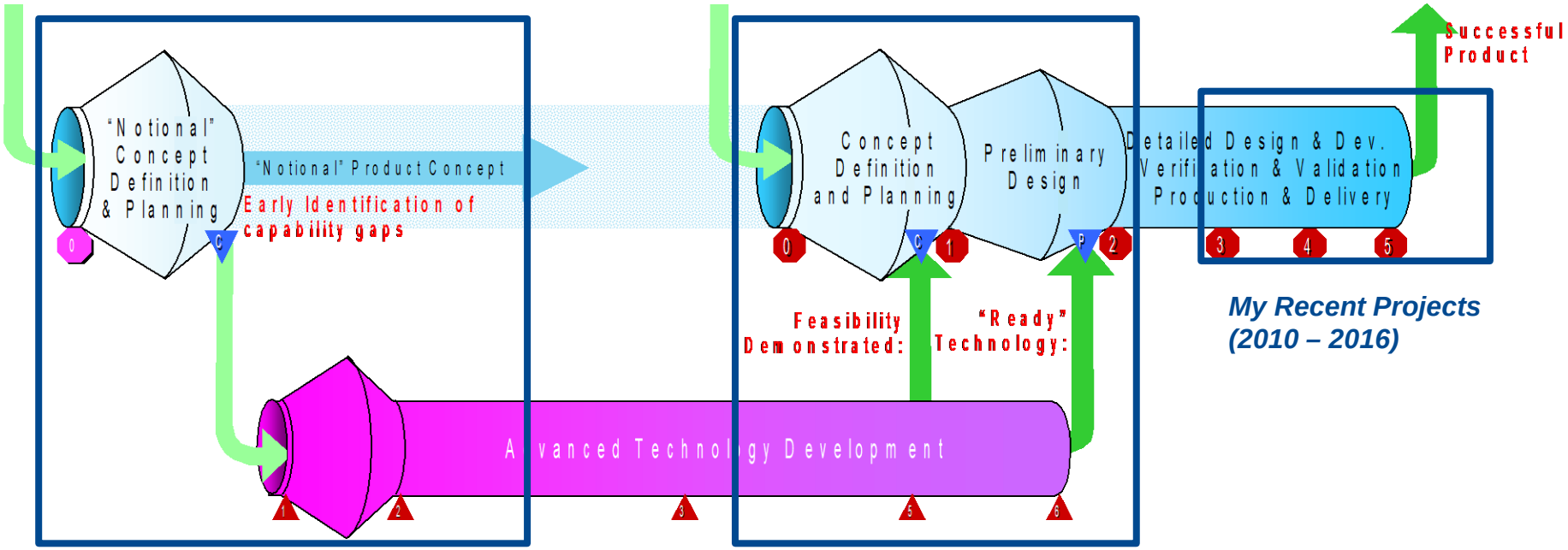
The Ideal: Green Field Product Development



Green field design: develop product from scratch; feed new technology / innovations into the architecture at the beginning of the pipeline

My Lens as a researcher and program manager:

- Focus is on team interaction; not on products moving through the pipeline.
- Common thread: What factors help or hinder how cross-functional teams exchange information as they conduct their product development activities?

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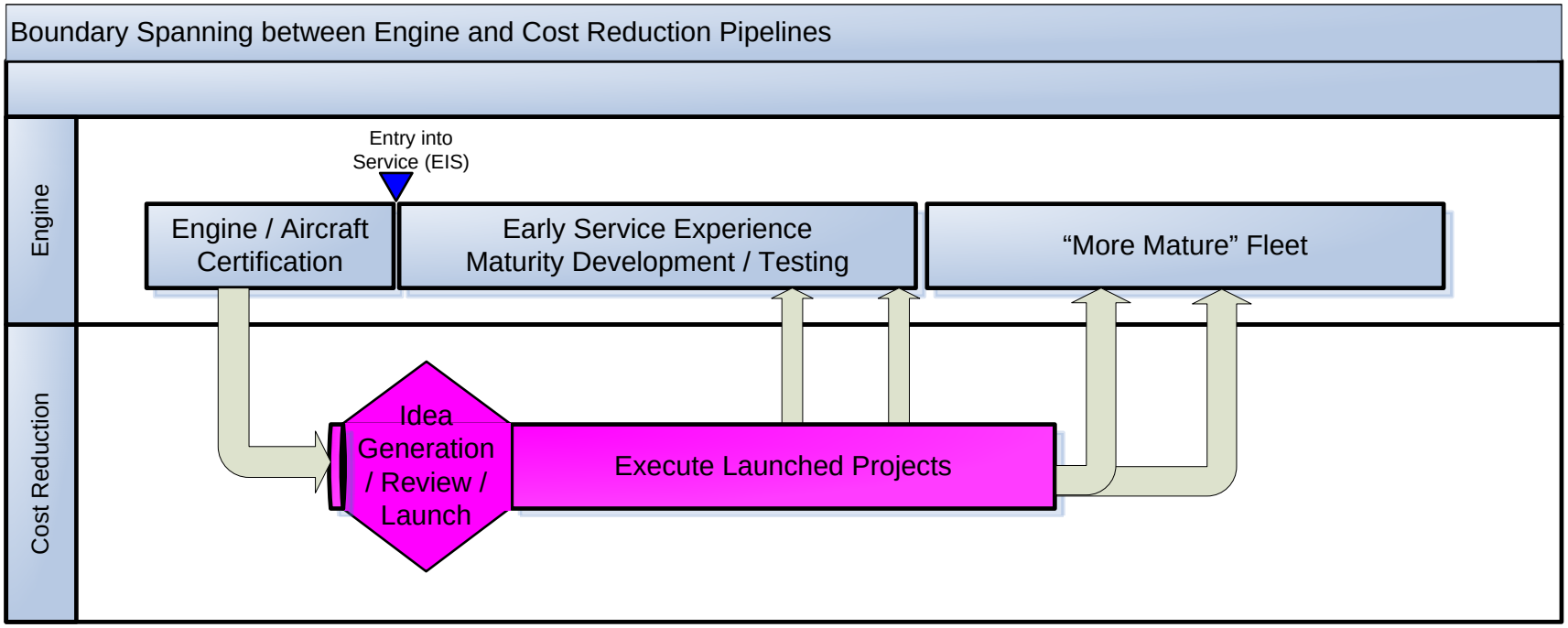
The Reality: Brown Field Product Development



Brown field product development:

- ***Changes are made to existing products***
- ***Constraints imposed by current architecture***
- ***Integration of improvements (e.g., cost reduction / reliability)***

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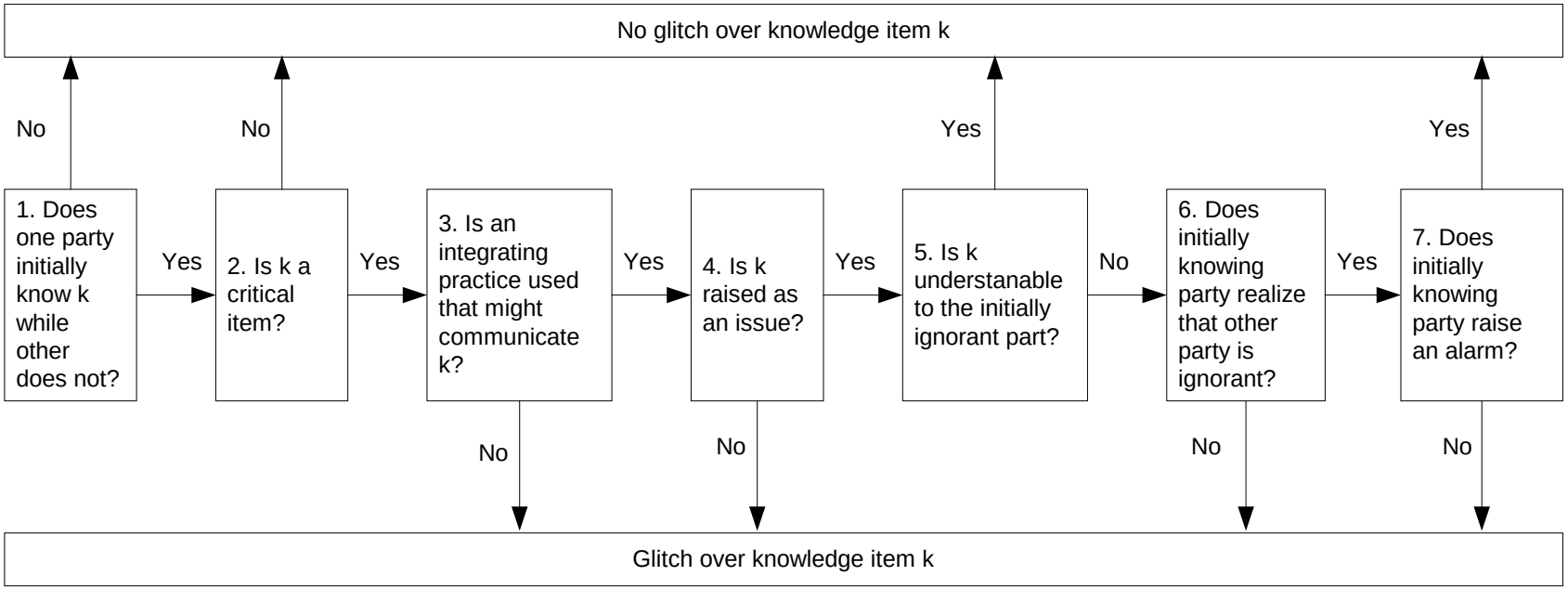
Problem Space: Glitches in NPI Teams



Glitch **– term originally coined in the context of software development, but also applies to:**

- **Product handoff from technology development into the NPI pipeline (cost of glitch is failed product)**
- **System architecture definition among cross-functional engineering teams (cost of glitch is late change and rework)**
- **Design change decisions for in-service modifications (cost of glitch is local optimization that doesn't weigh part cost against field service constraints)**
- **Engineering analysis of new conditions / impact of aircraft change (cost of glitch is incomplete requirements -> rework & cost / schedule creep)**

My Early Career

My Work Today

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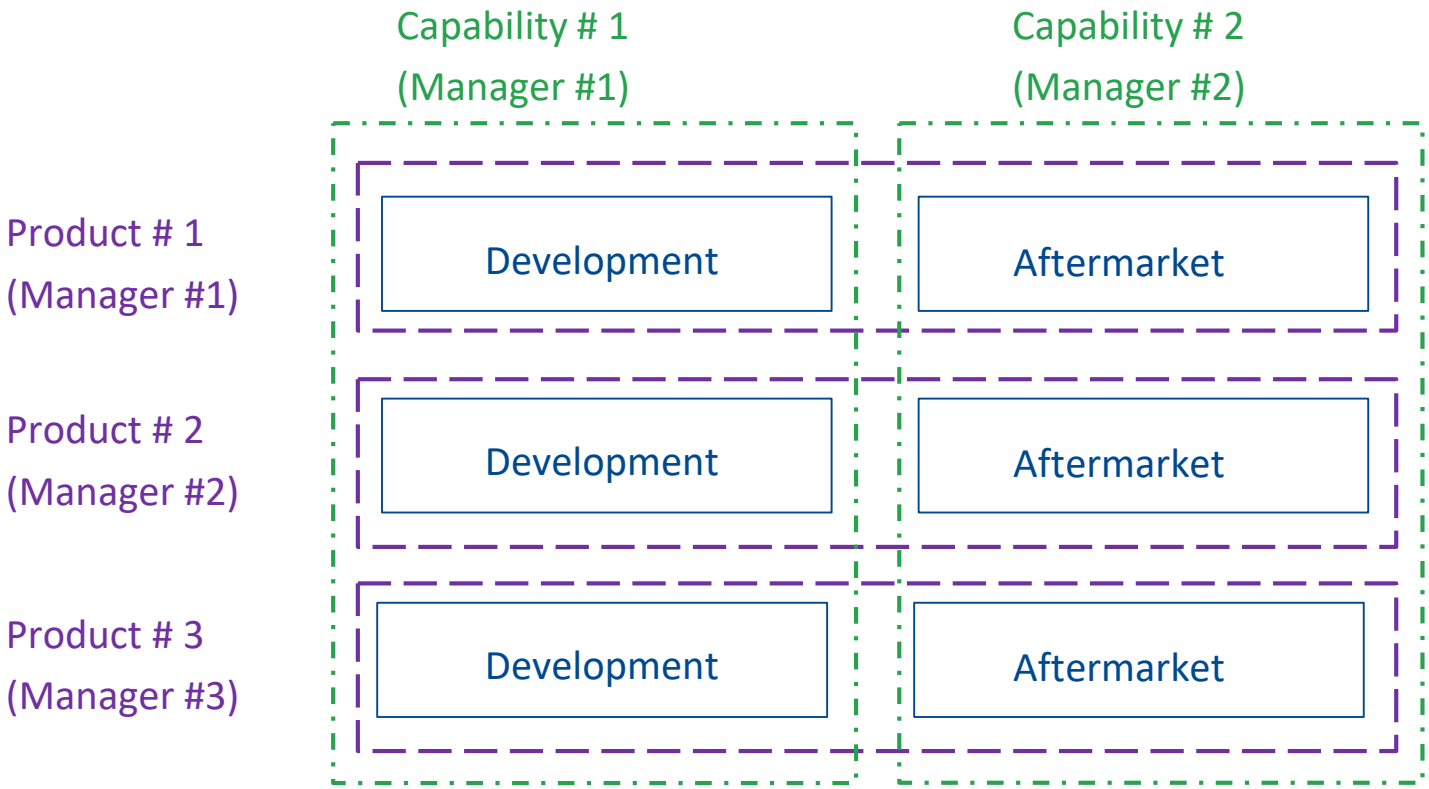
Problem Space: Glitch & Innovation Opportunities



"Old World" – Managed by Product Line

- "Minor fault lines" between Development and Aftermarket
- "Major fault lines" between product lines

"New World" – Managed by Capability

- Synergies aim to reduce fault lines between product lines
- Previous "minor fault lines" have potential to become major

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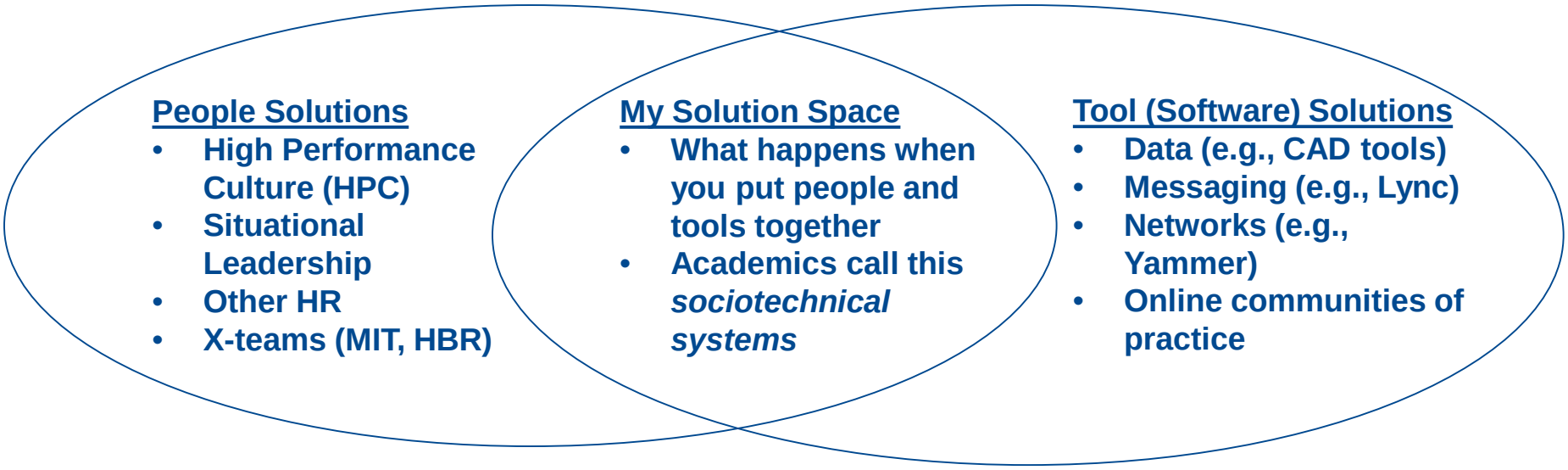
Solution Space: Anthropological Methods



People Solutions: suggest behavior, and leave application to be discovered
Software Solutions: suggest tool, and leave behavior to be discovered
Anthropologist: look at the how people use tools in context of specific groups / ecosystems

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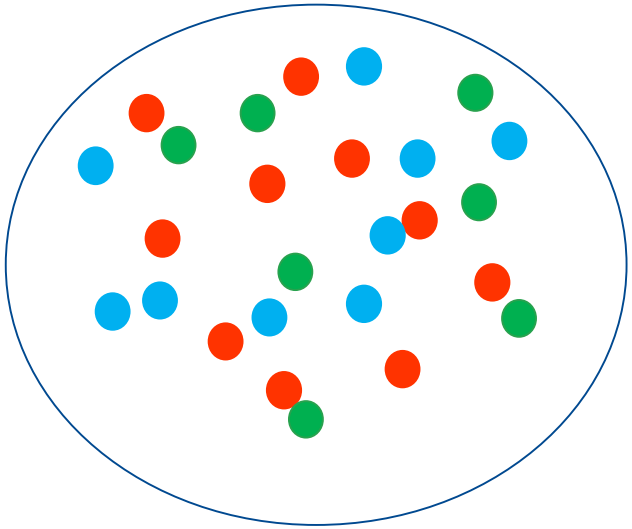
Solution Space: What's Wrong with the Status Quo?



Engineering Teams

- **Interactions are "seeds" that do or don't yield fertile project results**
- **Neutral fertility (blue dots above) lets project proceed**
- **Poor fertility (red dots above) reduces output & hazards project outcomes**
- **HPC works to increase fertility ratio (green dots above)**

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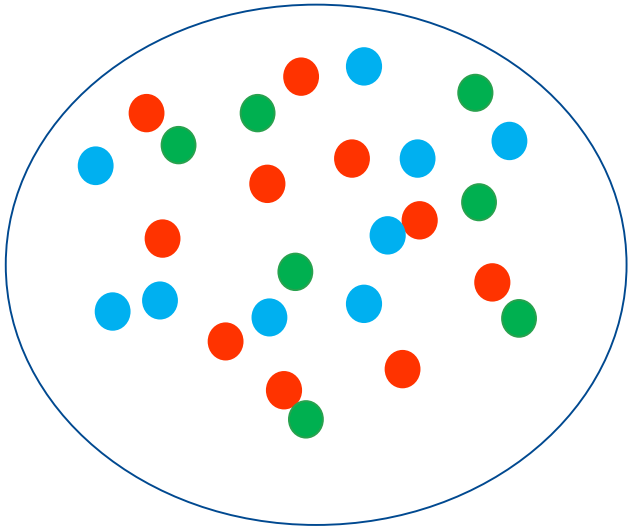

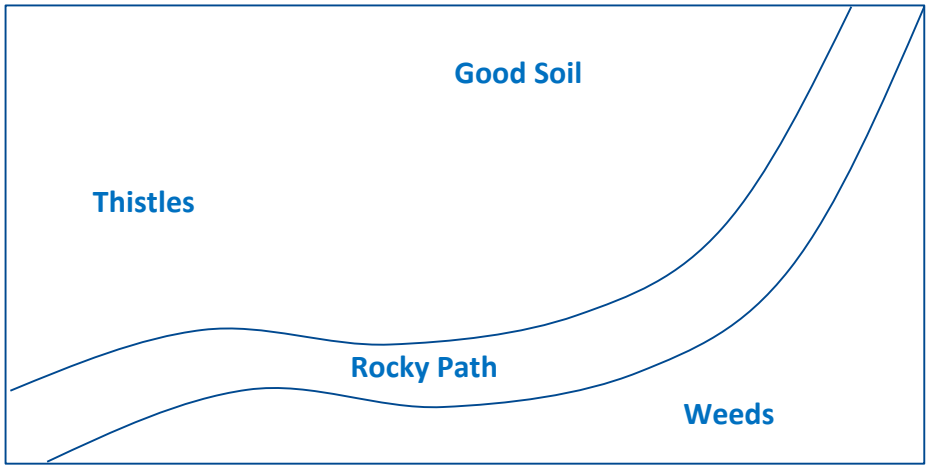

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Anthropological Methods

- Map the landscape for growing seeds
- Tell you where to plant
- Tell you how to plant "in context"
  - Combines don't work here; use a spade

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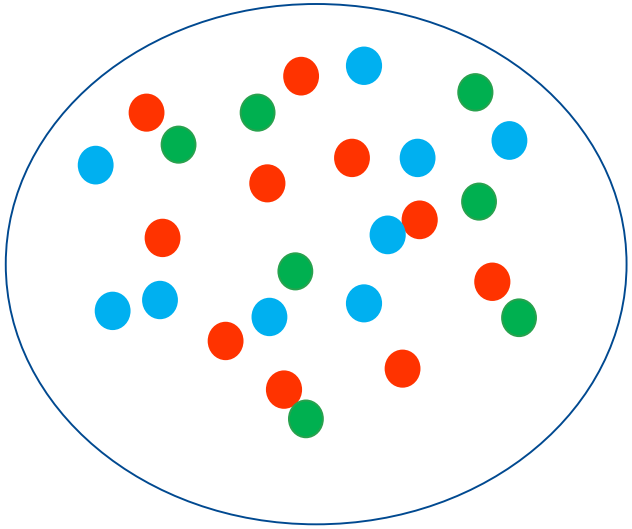
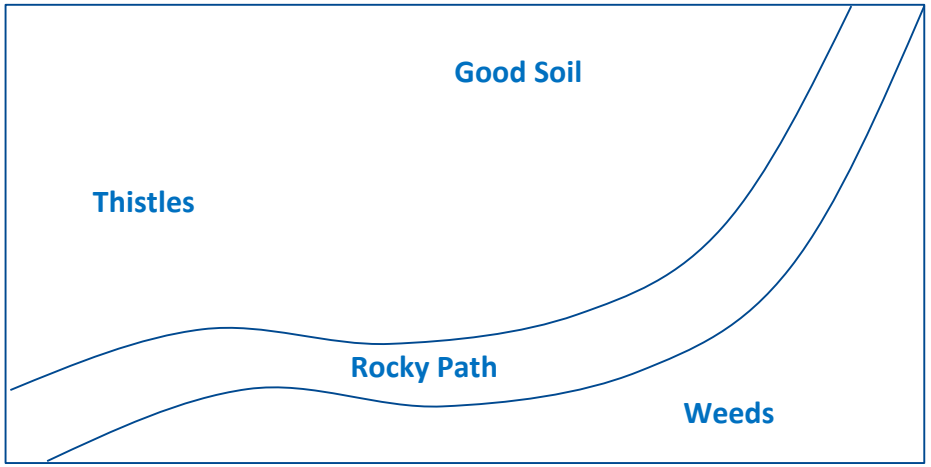
Solution Space: What's Wrong with the Status Quo?





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Example: Project Engineer calls a meeting

- Folks aren't talking – it's valuable
- Folks are talking – it's wasteful
- HPC increases courteous interaction
- Anthro provides situational judgment to decide if meeting is needed

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Solution Space: Mapping to Engineering Value*

Anthropology Question	"Bridge" Work	Engineering Value
Why won't you eat *{supposedly better food}*? Why won't you adopt *{supposedly better practice}*? Why are new tools being used not as we expected?	**Research opportunity: What could this look like?**	Why won't you use *{supposedly better new KM / CAD / etc tool}*? Why won't you use *{supposedly better SE tool}*?
How do humans forage for resources? • Pre-emptively • After a crisis	How do healthcare teams forage for information & mobilize resources? • During emerging epidemic / hurricane / snowstorm (Purdue)	**Research opportunity:** • **Project engineer meetings** • **Early V&V gaps**
Let's elicit taxonomies (because we know you don't use the scientific ones)	• Users don't apply impact / likelihood dimensions of risk • Finding "white space" for better patents (IUPUI)	**Research opportunity: What could this look like?**
What does a real _____ (e.g., Welsh person) do? • If living in Wales • If living in Iowa • If living elsewhere	• What does a real Systems Engineering do (Shawn's PhD)? • What does a culturally competent engineering student do (Purdue NSF project)?	What does an engineer do • When interacting with an arrogant SITEA counterpart? • When interacting with SITEB cowboy? **Research opportunity: What could this look like?**

** Table order is decreasing proximity based on Shawn's circle of influence*

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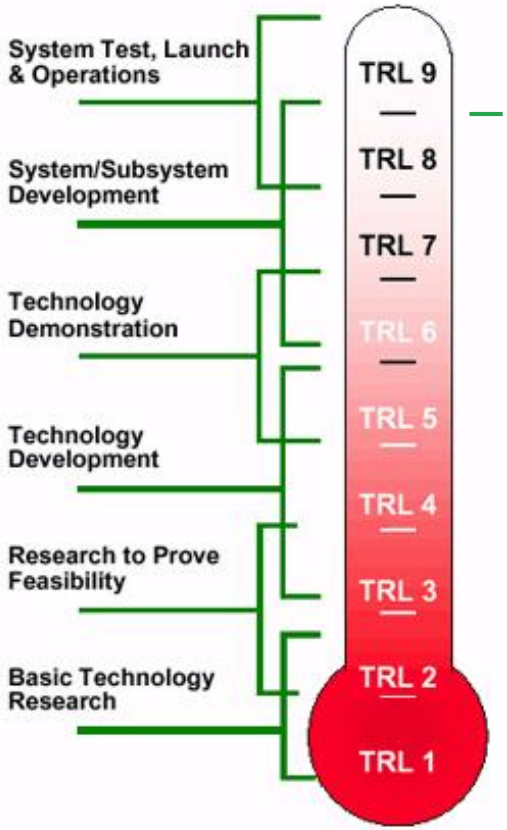
Methods on a Readiness Level Scale



Maturity "Waterline" to deploy in my workplace

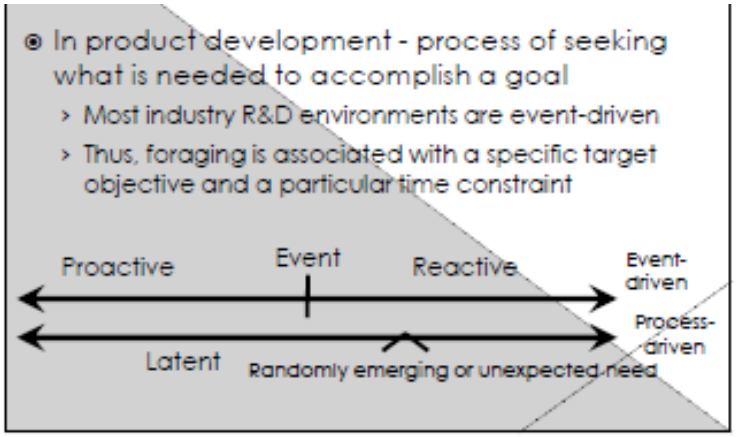
Consensus Analysis / Mental Models

Cognitive Domain Elicitation / Situational Judgment

Information Foraging

Ethnographic Decision Model (EDM)

Shawn's Experience



Transactive Memory Systems (TMS)

Behavioral Operations

Multi-team Membership (MTM)

Multi-team Systems (MTS)

Shawn's Literature Review & "Idea Hopper"

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Potential Value Proposition for IP Landscape

This could be an area that generates intellectual property

- Baba, M. L. (1998). Method for Mapping Joint Ventures and Maps Produced Thereby, U.S. Patent, No 4773862. Washington, DC: U.S. Office of Patents and Trademarks

- Clancey, W. J., Torok, D. M., Sierhuis, M., van Hoof, R. J. J., & Sachs, P. (2001). Simulating Work Behavior, U.S. Patent, No 6216098. Washington, DC: U.S. Office of Patents and Trademarks.

- Jordan, B., Goldman, R., & Sachs, P. (1998). Representing Work Practices, U.S. Patent, No 5745113. Washington, DC: U.S. Office of Patents and Trademarks.

- Sengir, G. H., Trotter, R. T., Kulkarni, D. M., Catlin, L. B., Briody, E. K., & Merwarth, T. L. (2005). System and Model for Performance Value Based Collaborative Relationships, U.S. Patent, No 7280977. Washington, DC: U.S. Office of Patents and Trademarks.

Summary Points

We know that

- Team interaction has a non-trivial impact on cost / schedule adherence
- Cross-functional interaction is supposed to foster innovation

We also know that

- We don't really understand how to make team interaction reliable
- Some of it is personality
- Some of it is experience
- Some of it is under organizational control (that elusive thing called "culture")
- An awful lot of it is left to chance

It doesn't have to be this way

- Mature methods from social science (anthropology) can address team problems we leave to chance
- Engineering research is paying attention to these methods.

  It's a major research stream from the NSF

  Universities in Indiana (and elsewhere) are doing this research
- This means the "maturity gap" to apply these methods in Engineering Organizations is closing

What could the research / practice overlap look like??

- Let's talk – that's why I'm at the summit

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Questions?

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NSF Research Projects in Progress Locally

Project	Where being worked
Becoming Boundary Spanners: Investigating, Enhancing, and Assessing the Experiences of Early Career Engineers	Purdue Engineering Education (Brent Jesiek)
Global Engineering Competency: Definitions, Development Paths, and Situational Assessment	Purdue Engineering Education (Brent Jesiek)
Developing Globally Competent Engineering Researchers	
Revolutionary Change to Mechanical Engineering Education	Purdue Engineering Education (Ed Berger)
Engineering and Science Intellectual Property Project (navigating IP landscape and system interactions for new patent ideas)	IUPUI Technology Leadership and Communication (Charlie Feldhuas)
Modeling information resources in complex environments	Purdue Industrial Engineering (Barrett Caldwell)

- *Search criteria: topic is at least "bridge" maturity; access is within a day trip*
- *Management research at Kelley / Krannert isn't there (Krannert is starting to probe)*
- *Ohio State Systems Engineering is moving this direction, but the bridge isn't as mature*

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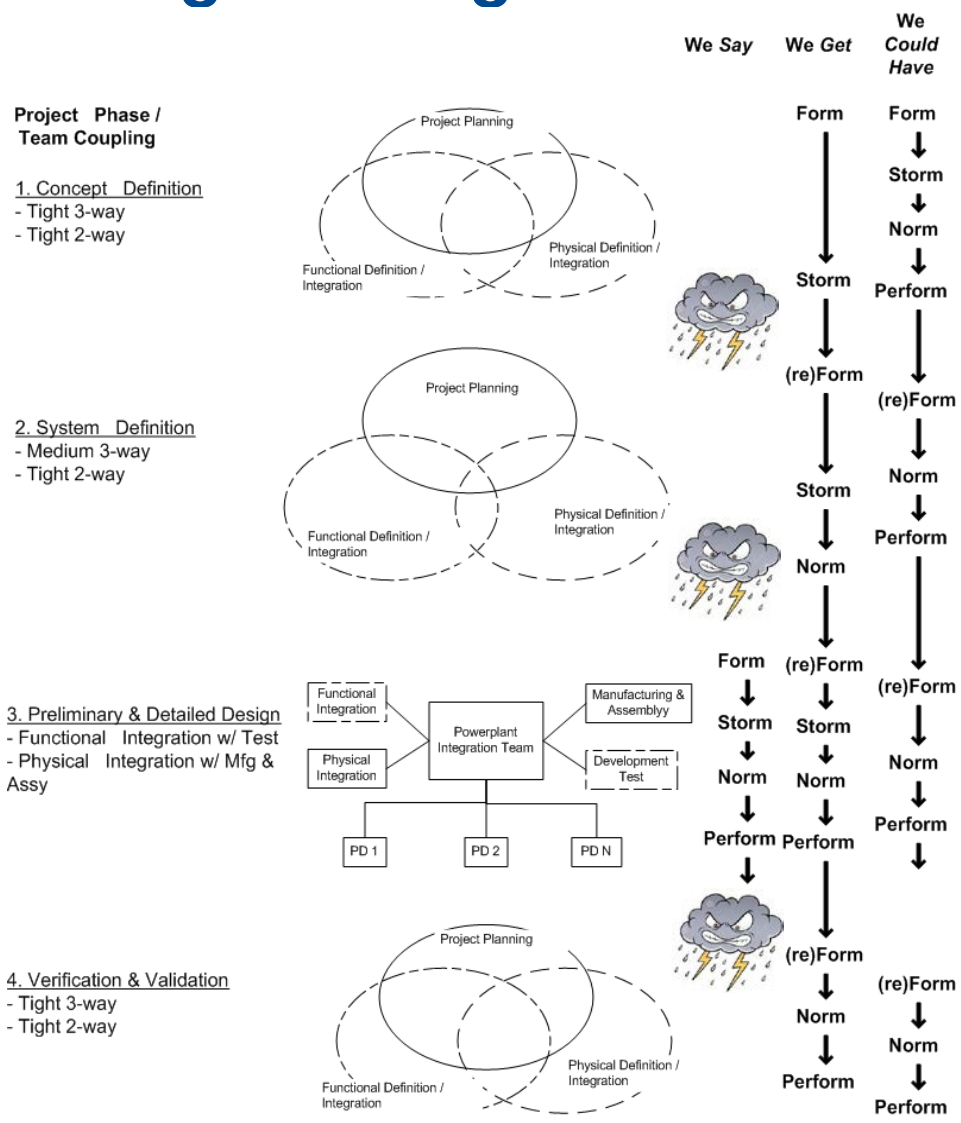
Value Proposition for Engineering Teams

- *We say*: our teams are formally structured with well-defined roles, responsibilities, and boundaries for information flow (stage 3 on the right)
- *But truthfully*: our teams operate with degrees of "skills overlap" that varies with project life-cycle, complexity of the project scope, and "storm-fronts" that occur when direction or team-members change (stages 1 – 4 on the right)
    - All 4 stages collaborate, *but they do so in very different ways*
- In "fundamental physics" terms, this deals with situational awareness, empathy, and knowledge boundary-spanning.
- Process can't enforce these skills; informal exchange doesn't guarantee them; teams underperform without them because they're vulnerable to glitches

- Like rapid prototyping of new parts, I think there is an opportunity to "rapid prototype" new ways to guide teams through their life-cycle and storm clouds. I just don't know what it is yet.



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